

Technology of interdisciplinary open-ended designing in engineering education

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Abstract. Author's technology of interdisciplinary open-ended engineering is presented in this article. This technology is an integrated teaching method that significantly increases the practical component in the educational program. Author's technology creates the conditions to overcome the shortcomings in the engineering education. The basic ideas of the technology of open-ended engineering, experience of their implementation in higher education and the author's vision of the teaching technology are examined in the article. The main stages of development process of the author's technology of open-ended engineering to prepare students (bachelor) of technical profile are presented in the article. Complex of the methodological tools and procedures is shown in the article. This complex is the basis of the developed training technology that is used in educational process in higher school of engineering (UrFU). The organizational model of the technology of open-ended engineering is presented. Organizational model integrates the functions in the creation and implementation of all educational program. Analysis of the characteristics of educational activity of students working on author's technology of interdisciplinary open-ended engineering is presented. Intermediate results of the application of author's technology in the educational process of the engineering undergraduate are shown.

1. Introduction

Technical re-equipment of existing enterprises and creation of new innovative companies is the basis of modernization and development of Russia's economy [1]. The implementation of these ambitious objectives requires qualified engineering staff. They should be able to generate new ideas and convert them into design and technological solutions, to solve production problems and bring projects to commercial results.

Training requirements for system engineers and managers of engineering projects are determined from the above problems. They have to possess a sufficiently wide range of engineering, scientific, applied and economic competences, including interdisciplinary and managerial knowledge, in order to use them in the design and implementation of innovative technical systems. These abilities of the graduates are actually not formed in the traditional approach to engineering training. It is established that most young engineers do not have enough interdisciplinary knowledge in design and engineering activities. They have poorly formed such competencies as: «Development and execution of technical specifications for the product», «Trajectory optimization for solving engineering tasks», «Development of programs and methods of testing products», «The security of the designed product», «Functional and cost analysis of the designed product», «Implementation of design based on regulatory requirements» and a number of other.



The reasons for this situation are well known, they are generally related to the fact that modern Russian engineering education reduces systemic and does not focus on the full life cycle of an innovative product [2-4]. New methods of training are needed to eliminate these deficiencies, which correspond to modern requirements of scientific, technological and technological development [5-7].

2. The technology of open-ended engineering

One of the most promising methods of training engineers is open-ended engineering. The method of open-ended engineering is actively used in domestic universities, providing training for bachelors and masters in engineering and technical profiles. Most often it is used in the educational process in the following areas: construction [8-10]; mechanical engineering [11-14]; instrumentation and electronics [15, 16].

In these publications, usually the implementation of open-ended engineering is the fulfilment of a complex project task by students for several semesters (from two to five). The complex task contains several interrelated local assignments, which students carry out within the framework of course design in separate disciplines. Students combine the results and protect them as their final qualifying work in the last semester. In this regard, several authors note the need to adjust the curriculum to optimize the consistent implementation of the necessary course projects and to develop an integrated project task through the joint work of several departments. [9, 10]. In addition, the method of open-ended engineering is used both in the main educational process of the university, and in student circles and clubs [11]. Thus, open-ended engineering (in the widespread practice of its application) is a learning method, based on complex project tasks, which is mainly used as a means of creating a connection between course projects. It is implemented in individual and in group form of educational work and is provided by traditional methods. Open-ended engineering design creates the basis for the final qualifying work.

In the opinion of the authors, not all the possibilities of open-ended engineering are realized in the above experience. The main idea of the open-ended engineering in the educational process of the university is to make the project activity the main method of teaching. Accordingly, the content of open-ended engineering is the core of the practical interrelationship of different disciplines of the educational program with the provision of the interdisciplinary content of professional training.

The maximum effect in the implementation of this understanding of open-ended engineering is achieved only at creation of appropriate educational technology. The technology of open-ended engineering is proposed to be considered as a set of methods and tools for organizing the educational and project activities of students; simultaneously, the technology of open-ended engineering allows to optimize the structure and content of the educational program, which ensure the mastery of the contents of the academic disciplines and the interdisciplinary process of designing across the full life cycle of technical systems. This set of methods, methods and means of organizing the educational and project activities of students has a common logic and a certain sequence which allows to achieve the specified learning outcomes.

The open-ended project should be the backbone of the educational program for high-performance training and project activities. The individual stages and components of open-ended engineering should include design tasks for the majority of disciplines, as well as course projects and interdisciplinary projects of training modules. The logic and content of open-ended engineering should define the structure and content of the educational program and curriculum. This task is the most difficult in the creation of this technology, because it requires a radical change in the traditional approaches to the development of university educational programs of different levels (bachelor's degree, specialty and magistracy).

Technology of interdisciplinary open-ended engineering (IOEE) was developed for the original educational program of engineering bachelor degree in "System analysis and control" for the profile of design and engineering activities at the higher engineering school (Ural Federal University). Also, Kozubskij A. M., A. A. Oreshkin, G. G. Suhanov, V. O. Furin participated in the development of the technology of open-ended engineering and main modules of the bachelor's degree programs. The

development of IOEE technology is the integration of two counterpropagating processes: 1) the formation of the plan of project activities of students, the results of which correspond to the competence model of a graduate; 2) the formation of an educational program and curriculum that allow to implement of the open-ended engineering with the maximum results of project activities and training. The logic and composition of actions for solving this problem are presented in Figure 1.

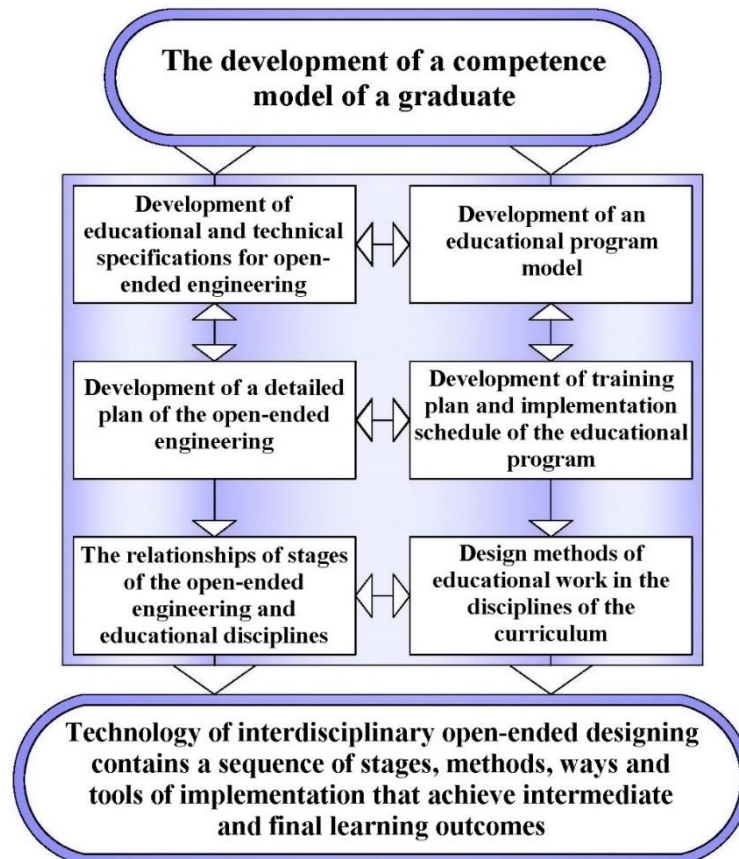


Figure 1. The process of developing the technology of interdisciplinary open-ended engineering.

Interdisciplinarity of the technology of open-ended engineering is reflected in the organization of work of students, aimed at analysis and identification of the various relationships in the content of the curriculum; all this is used to develop open-ended project. This work is carried out in the form of separate project assignments, as well as in the development of interdisciplinary projects for training modules. Students use analysis and identify the relationships between the content of different disciplines for the development of effective design solutions at different stages of IOEE technology. The interrelationships between technical, natural-science and technological training courses, as well as interrelationships with economic, managerial, psychological, ergonomic and other disciplines are considered in IOEE technology.

The basis of the developed technology of interdisciplinary open-ended engineering is the following set of methodological tools and procedures (see below). They manage the project and training activities of the students.

1. Problem statement of the open-ended engineering and requirements to its outcomes.
2. Educational technical specification for the development of the interdisciplinary open-ended engineering. This specification is developed and adjusted in collaboration between student and teacher

during the entire period of execution. It contains the development stages of the open-ended engineering with complex of the project tasks and assignments for academic disciplines.

3. The requirements for protecting intermediate results of the open-ended engineering. They also contain requirements for course projects and interdisciplinary projects for training modules.

4. Methodical recommendations for implementation of the results for all design stages. For example, the design results can be presented in the form of prototypes from prototyping and structural materials.

5. Consultation of qualified engineers working in manufacturing at all development stages of the open-ended engineering.

6. The final presentation of the main results of the open-ended engineering at key stages. The presentation must contain the full life cycle of the developed technical system.

7. Adaptation of the open-ended engineering to the requirements of the qualification work and its public defense.

3. Training and production workshop

Special practice-oriented training course ("Training and production workshop") was developed for the organization and implementation of open-ended engineering on this technology. The total complexity of the course is 18 credits, it continues from first to eighth semester. The programme of the workshop is built in accordance with IOEE technology [17]. The material and technical base with modern equipment of machinery production was established at the higher engineering school of UrFU for the implementation of the workshop. The structure of the IOEE technology and its integrating functions in the educational program are shown in Figure 2.

Open-ended engineering provides a two-way reciprocal process between the project activity and of educational-cognitive activity of students at all stages (Figure 2). The educational and practical activities of students in the framework of open-ended engineering are organized in a special way. In particular, engineering tasks are projected onto the content of academic disciplines studied by students in parallel. Moreover, the educational work in most academic disciplines should provide an opportunity for students to solve the tasks of an open-ended project. Thus, the implementation of the educational program is preparing students for future activities, as well as a key condition for solving engineering problems that students perform in the development process of the open-ended project.

Qualified engineers of a design and engineering companies are involved as consultants for the implementation of this approach on open-ended engineering. They participate in the evaluation and discussion of the design results made by students about once every 2-3 weeks.

Analysis of the implementation of design technology has shown that educational and project activity is organized as a result of its use. At the same time teaching and project activities:

- 1) ensures the creation of a real project of a technical system relevant for some industry;
- 2) integrates the content of the educational program and determines the main vector of training;
- 3) includes the implementation of all phases of the creation of a new technical system, ensuring the design in view of the full life cycle;
- 4) activates the interdisciplinary process of using knowledge from different disciplines, providing formation of professional competences of the graduate;
- 5) brings together the educational and professional activities of the engineer, which constitute a complex of different types of individual and collective action;
- 6) implements the CDIO ideology aimed at training comprehensively educated engineers who can plan, design, manufacture and operate of a complex engineering systems;
- 7) determines the actual practical-oriented theme of the final qualifying work;
- 8) forms a creative outlook of the graduates.

The development of a design engineer is quite dynamic with the use of IOEE technology. This can be seen from the following learning outcomes. After one year of study students are able:

- to determine the content of the stages of the full life cycle of products and plan stages of the project;
- to work in teams, using constructive ways of interaction to prevent conflicts;
- to create a functional model of the product from prototyping materials;

- to implement a solid and mathematical modeling in development of design documentation;
- to structure the information in the form of diagrams, tables, figures, charts and criteria-based dependency.

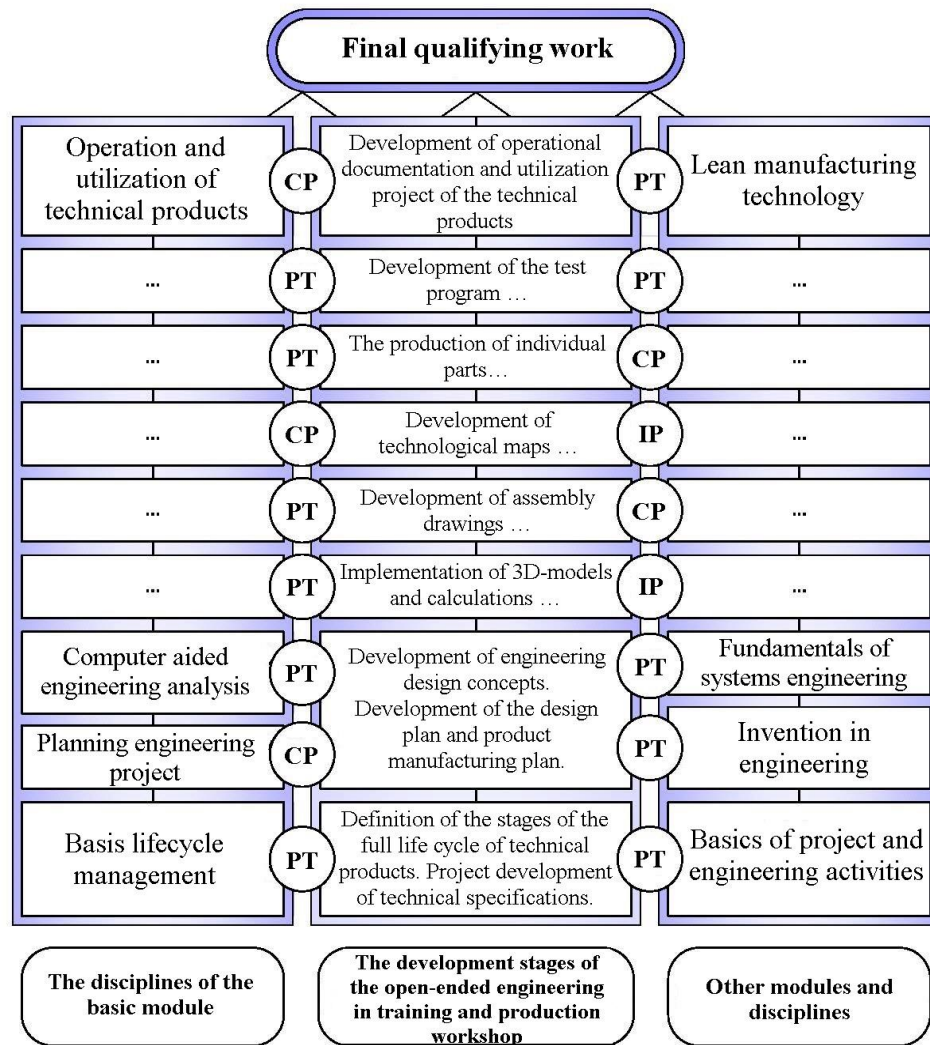


Figure 2. The organizational model of the technology of open-ended engineering: PT – project tasks; CP – course project; IP – an interdisciplinary project on the training module.

After two years of study the students are able:

- to prepare scientific and technical reports, reviews, opinions, and conclusions in accordance with the requirements of the engineering tasks;
- to choose the main design and technological characteristics of the product and justify them with calculations;
- to apply the regulatory requirements in the design work;
- to analyze the requirements of an operational environment in preparation of technical solutions;
- to produce a feasibility study on developing the product;
- to take into account the existing technological capabilities when making design decisions.

Students prepare a progress report and defend it before the commission at the end of each year of study. University teachers, engineering consultants and representatives of industrial enterprises are members of the commission.

4. Conclusions

Thus, the interdisciplinary open-ended project is a project of real technical systems related to the field of professional training of student. Students systematically work on the project throughout the period of study, or a substantial part of it. At the same time, the tasks of the project activity are interrelated with the learning outcomes specified in the educational program. Accordingly, the content of the educational program and curriculum are adapted to the stages of open-ended project. The tasks and content of the project are determined in accordance with the opportunities of optimal implementation of the educational program. As a result, a new model of a practice-oriented educational program is formed, which determines the priority of educational and project activities. A graduate of this program knows and understands the contents of the full life cycle of technical systems and has experience of its implementation. Thus, the professional competences of the design and technological activities necessary to create a new product are formed by the graduate.

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